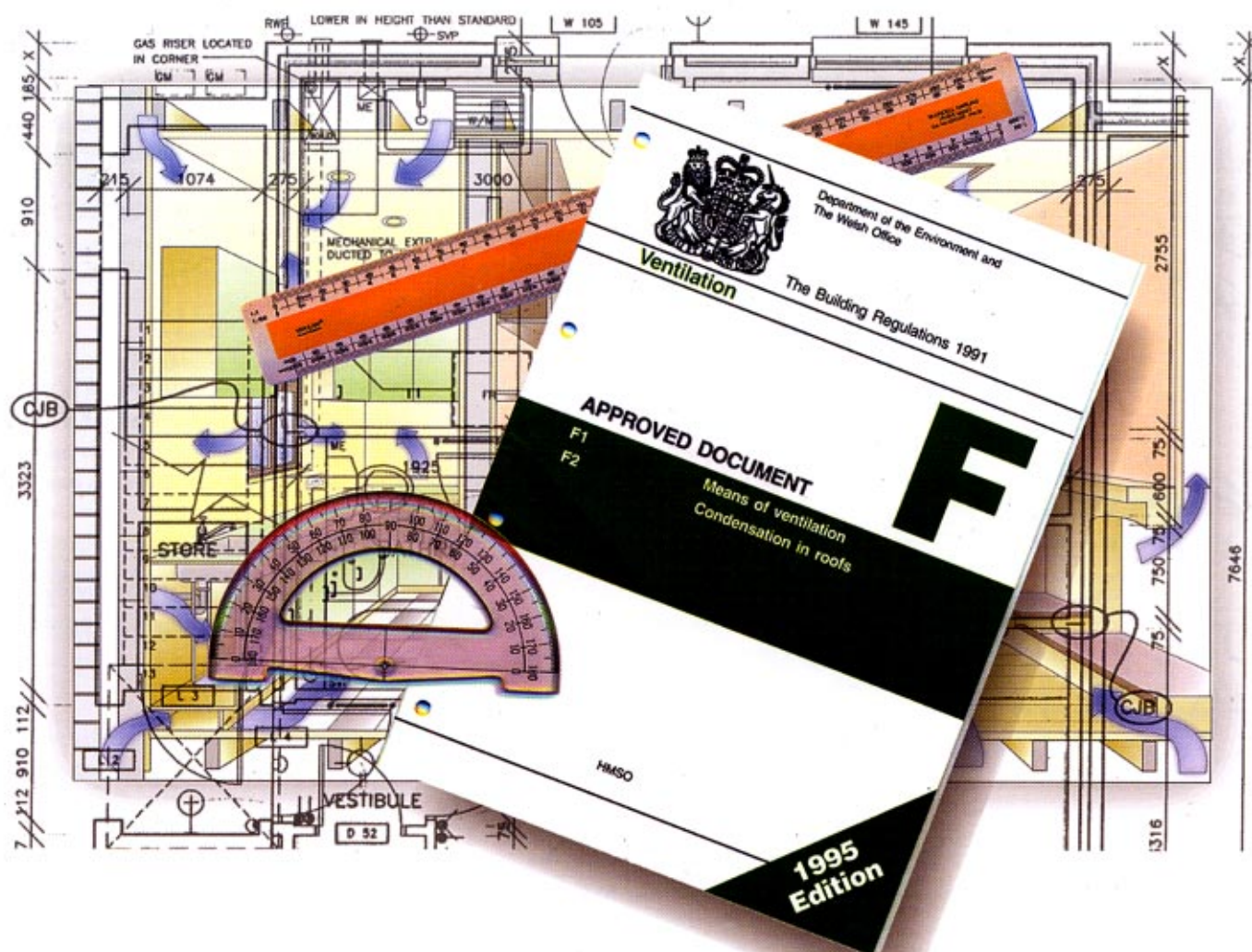


Energy-efficient ventilation in housing

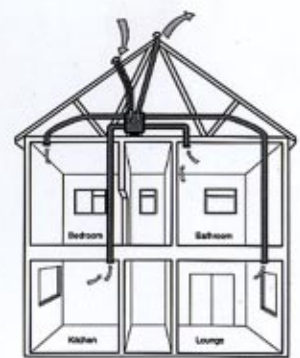
A Guide for specifiers on the requirements and options for ventilation



ENERGY EFFICIENCY

**BEST PRACTICE
PROGRAMME**

1 INTRODUCTION



All dwellings need a supply of fresh air, for the health and comfort of the occupants, the control of condensation, the removal of pollutants, and to ensure the safe and efficient operation of some combustion appliances. However, ventilation is something which, all too frequently, happens by accident rather than by design, and leads to ventilation rates which do not match the needs of the dwelling or the household. To achieve an energy-efficient standard of ventilation requires consideration of both the building fabric and the efficiency of the ventilation system. Whether designs for new or existing buildings are under consideration, ventilation should be thought of as part of an integrated design approach for achieving energy efficiency. Thermal insulation, heating systems and controls, and householder advice are important aspects to consider during the design process.

Traditionally, natural air infiltration has been relied upon to provide ventilation in many UK dwellings during the heating season. This can result in excessive ventilation rates that increase energy consumption for space heating, and cause discomfort to occupants due to cold draughts. Energy use due to ventilation accounts for approximately a third of space-heating energy

demand in an older dwelling, and up to a half in an energy-efficient design. Equally, too little ventilation leads to poor indoor air quality and occupant concerns over the removal of pollutants. The objective of a good ventilation strategy is, therefore, to provide a balance between energy efficiency and indoor air quality.

ABOUT THIS GUIDE

This Guide has been prepared to assist architects, surveyors and specifiers to understand the issues associated with energy-efficient ventilation and the types of systems that are available to provide satisfactory ventilation rates in all dwellings. The Guide explains why ventilation is important, its impact on achieving the efficient use of energy, the importance of airtightness, and describes the advantages and disadvantages of a range of ventilation systems. The guidance is presented in two parts:

- general issues and theory relating to ventilation
- ventilation options.

References are given to more detailed information relating to specific design issues and a glossary of terms is included below.

GLOSSARY

Ventilation rate

Rate at which air within a building is replaced by fresh air. May be expressed as:

- number of times the volume of air within a space is changed in one hour (air changes per hour)
- rate of air change in volume and time, eg litres per second (l/s).

Air leakage rate

Movement of air, both into and out of the building via the cracks and gaps in the building envelope. Expressed in air changes per hour (ach) at 50 Pascals (Pa) pressure difference (page 6).

Background ventilation

Finely controllable method of providing fresh air to a room to meet the minimum ventilation requirements.

Rapid ventilation

Method of providing short-term high rates of ventilation in individual rooms on demand.

Extract ventilation

Provided in rooms likely to be a source of pollution or odour.

2 WHY VENTILATE?

Ventilation is necessary to maintain a healthy and comfortable internal environment for the occupants, to rapidly remove pollutants such as moisture, and to provide an air supply to open-flue appliances.

The provision of ventilation openings for dealing with combustion air supply and for open-flue appliances is documented in UK Building Regulations, and is not covered in this guidance.

There are different types and sources of pollution within the home, for example:

- moisture
- volatile organic compounds (VOCs), such as formaldehyde
- allergens (eg from house dust mites)
- oxides of nitrogen
- carbon monoxide
- carbon dioxide (CO₂)
- tobacco smoke
- odours.

Moisture is generally assumed to be the most significant of these because of the high rates of generation from activities such as cooking, bathing and laundry, and of the problems associated with condensation and mould growth. It follows that, if the ventilation strategy is based on controlling this principal pollutant, then, generally, the other indoor pollutants will also be adequately controlled. The typical requirements for fresh air to meet our metabolic requirements and to dilute some pollutants are illustrated in figure 1.

Research has shown that if relative humidity levels exceed 70% for prolonged periods there is a high probability that condensation occurring on cold surfaces will lead to mould growth^[1]. Research has also established that a whole-house ventilation rate of 0.5 to 1.0 air changes per hour (ach) will usually be sufficient to keep relative humidities below 70%^[2].

Although the Building Regulations relate to new buildings, the guidance on ventilation is applicable to existing dwellings. The Regulations are concerned with minimising the risk to health from the build-up of pollutants. The Approved Document provides guidance on satisfying the requirements of the Regulations by the provision of background, rapid and extract ventilation.

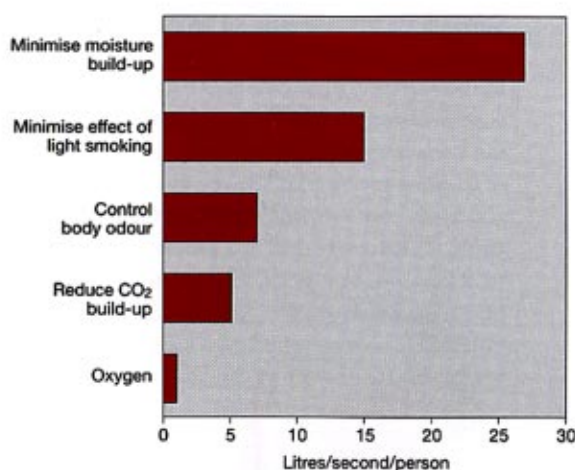


Figure 1 Fresh air ventilation requirement

3 THE PRINCIPLES/WHAT VENTILATION RATE?

THE PRINCIPLES

Ventilation can be defined as the exchange of stale indoor air with fresh outdoor air, through purpose-provided openings, and through cracks and gaps in the building envelope. The uncontrollable component of this ventilation is referred to as 'air infiltration' or 'air leakage'. There are two natural mechanisms that drive ventilation:

- the effect of wind, resulting from air movement around and over the building
- the 'stack' effect, resulting from the temperature difference, and therefore density, between the indoor and outdoor air.

Before the Building Regulations set a requirement for purpose-made provision for ventilation, many dwellings in the UK relied on these natural driving forces for ventilation (apart from windows). This is provided via the numerous air leakage routes (cracks and gaps) in the building envelope. In consequence, these dwellings may be over-ventilated and the highest ventilation rates will not necessarily occur when needed, ie during times of moisture production. The energy consumption, and hence cost associated with this, is illustrated in figure 2. This shows that, as a percentage of the total heat loss, ventilation losses have increased as insulation standards have improved. In well-insulated houses the ventilation losses can be responsible for nearly half the total loss.

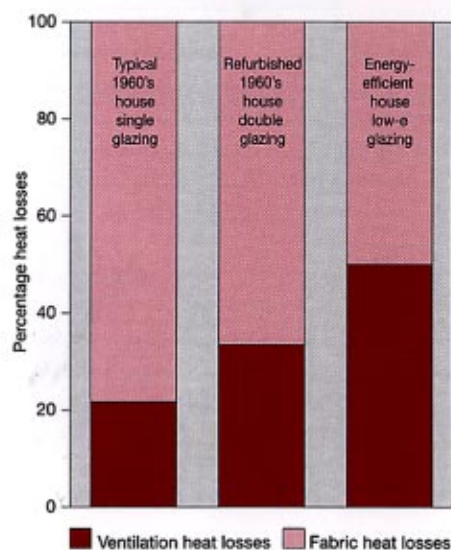


Figure 2 Comparison of ventilation heat loss and fabric heat loss

The natural mechanisms described can be supplemented, or replaced, by a variety of mechanical systems.

WHAT VENTILATION RATE?

It has been demonstrated that a whole-house ventilation rate of between 0.5 ach and 1.0 ach is normally sufficient to control moisture build up^[3]. To achieve this, a percentage will be contributed by air leakage (infiltration), and the balance by a purpose-made provision for ventilation. The objective of a good ventilation strategy is, therefore, to provide a balance between energy efficiency and indoor air quality. This has led to the concept of 'build tight – ventilate right'^[3], where the principle is to minimise uncontrolled air leakage through the building envelope, and provide an adequate ventilation rate via a controllable system. This can be by natural or mechanical means, or a combination of both.

Figure 3 illustrates the impact of uncontrolled air leakage on the ventilation rate. The greater the air leakage, the greater the ventilation rate and the more varied and uncontrolled it will be. Reducing air leakage is often essential to bring the ventilation rate within the target zone of 0.5-1.0 ach.

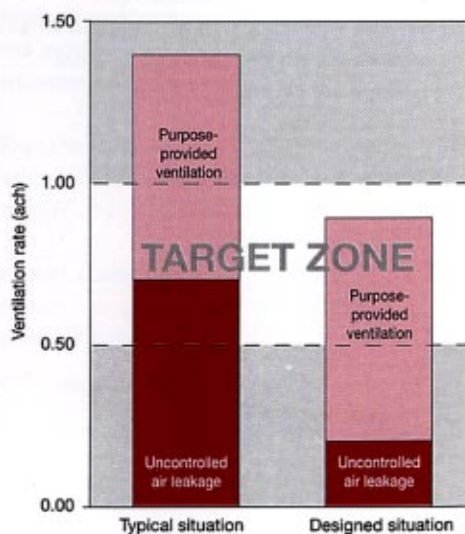


Figure 3 The impact of air leakage on the ventilation rate

4 IMPROVING AIRTIGHTNESS

Air leakage is the uncontrolled movement of air, both into and out of the building, through the cracks and gaps in the building envelope. The principal areas through which leakage can occur are illustrated in figure 4 and can be summarised as follows:

- joints between structural elements, eg floors to walls
- joints around components within elements, eg windows and doors
- the components themselves, eg opening windows, mortar joints
- services installations
- porous materials.

While air leakage can be a direct leak, for example around an opening light in a window, most leakage follows a more complicated path through a series of routes, as illustrated in figure 5.

In consequence, air leakage can be difficult to trace and seal effectively once construction is completed. Approved Document L to the Building Regulations suggests some simple guidance on achieving better standards of airtightness in new dwellings. More

detailed guidance is given in Good Practice Guides 93 to 110. Guidance on improving the air leakage characteristics of existing houses is given in Good Practice Guide 224 (see Further Reading).

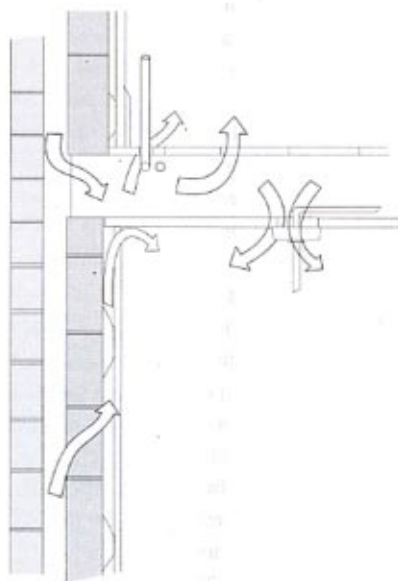


Figure 5 Indirect air leakage rates

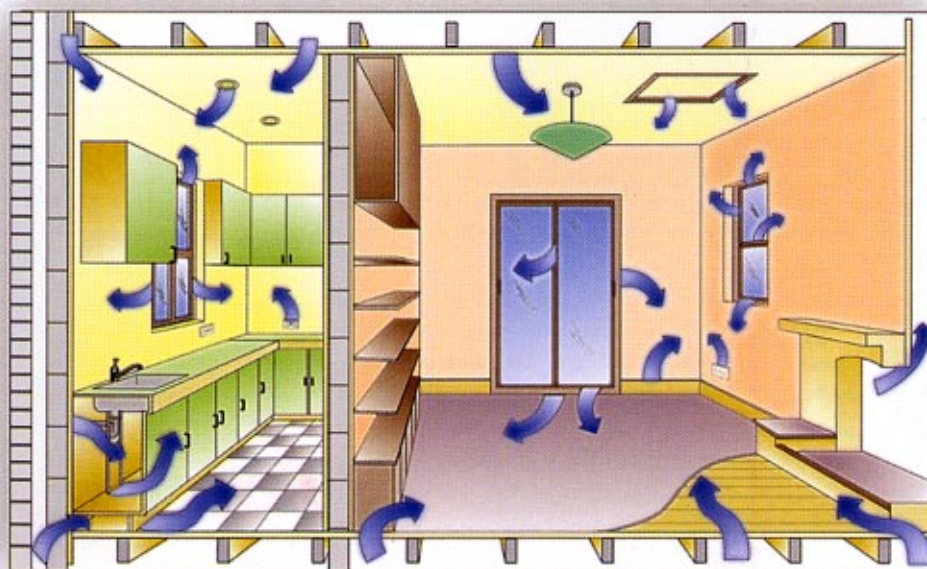


Figure 4 Examples of typical air leakage paths

IMPROVING AIRTIGHTNESS

The standard of airtightness achieved within the house will largely dictate the typical ventilation rates achieved. The airtightness of UK dwellings covers a wide range, from as low as 2 ach to above 30 ach at 50 Pascals (Pa). These values correspond to air infiltration rates of approximately 0.1-1.5 ach under average weather conditions. The average value for UK dwellings is about 14 ach at 50 Pa, equivalent to an average infiltration rate of around 0.7 ach. This means that the uncontrolled air leakage in an average dwelling is already achieving a ventilation rate within the target zone. Any further provisions, such as extract fans, will increase ventilation losses. The uncontrolled nature of this infiltration means that in windy conditions the infiltration rate alone will exceed the target rate. To achieve the energy-efficient ventilation rate of 0.5 ach suggested earlier, the rate of air leakage needs to be reduced significantly.

To check that an acceptable level of air leakage is achieved in practice, a measurable standard should

Ventilation system	Suggested maximum leakage rate
Local extraction and background ventilation	5-7 ach at 50 Pa
Whole-house ventilation systems	4 ach at 50 Pa

Table 1 Suggested air leakage rates for different ventilation options

be specified and tests carried out after construction to demonstrate compliance with this standard.

Suggested standards for air leakage rates, depending on the ventilation method chosen, are given in table 1. Rates are applicable to both existing and new-build dwellings.

These rates can be measured using the fan-pressurisation technique, as described in the box below.

FAN PRESSURISATION

The fan-pressurisation technique was devised to measure the airtightness of the building envelope. The pressurisation test uses a fan mounted into a dummy door to induce both positive and negative pressure differences across the building envelope while measuring the air flow through the fan. The air leakage rate can then be calculated and quoted for a standard 50 Pa pressure difference. While the results are measured in terms of ach, similar to ventilation rates, the pressure differentials used are several times greater than occur in practice.

The results are not, therefore, directly comparable to ventilation rates. A recommended procedure for measuring the airtightness of dwellings has been developed by BRE⁽⁴⁾. This allows the results to be used for:

- comparing the airtightness of the dwelling with recognised standards
- identification of air leakage paths and the rate of air leakage
- an assessment of the potential for reducing air leakage within a dwelling
- measuring the improvement following airtightness work.

*An ISO Standard is currently being prepared which will replace this procedure.

5 INSTALLATION ISSUES/VENTILATION OPTIONS IN DWELLINGS

INSTALLATION ISSUES

Under the Best Practice programme, a number of projects to assess the energy efficiency of alternative methods of ventilation have been carried out. Often, the success of these schemes could have been improved by a greater degree of understanding by the tradesmen installing the systems. Many manufacturers operate registered installers' schemes to help train and monitor contractors in the correct installation of their systems. Some experiences of poor installation practice from these schemes are summarised below. These issues should be considered when assessing the ventilation options on the following pages.

Local extract fans

- Flexible ducting (installed in a roof space to connect ceiling-mounted fans to an external terminal) had not been adequately clamped to the terminal and could have become detached. Warm, moist air would then be discharged straight into a cold loft space, giving a significant risk of condensation.
- Humidity sensors had been incorrectly sited and wired, and no attempt made to commission them on site.
- Isolating switches had been installed close to fans, leading to occupants turning them off. This problem may be reduced by locating isolating switches remote from fans, eg airing cupboards (except where emergency access is required to prevent danger).

Passive stack ventilation

- Insulated, flexible ducting, installed in the loft space to connect the inlet to the external terminal, had not been cut to length or adequately clamped to roof structure and terminal.
- The choice or location of the roof terminal had been inappropriate.

Mechanical whole-house ventilation systems

- To operate efficiently, the systems need to be balanced to give a slight under-pressure in the house. Often, systems are not properly commissioned, resulting in a poorer operating performance.

VENTILATION OPTIONS IN DWELLINGS

The following sections of the Guide deal with five systems/methods for providing ventilation to dwellings. A short description of each system is given, with a number of advantages and disadvantages, and typical applications. The systems considered are:

- passive stack ventilation (PSV)
- local extract fans
- heat recovery room ventilators
- mechanical supply ventilation
- whole-house mechanical ventilation with heat recovery (MVHR).



Figure 6 Badly installed flexible ducts with excessive length of ductwork and tight bends

6 PASSIVE STACK VENTILATION

APPLICATIONS

- New build.
- Major refurbishment.

ADVANTAGES

- No direct running costs associated with the system.
- System will last the life of the building.
- Silent in operation.
- Provides a level of continuous background ventilation.
- Government-sponsored research has demonstrated the systems are capable of controlling relative humidities below 70% (the critical level).
- Systems have proved popular with occupants.
- No electrical connection required.

DISADVANTAGES

- Existing house layouts can make it difficult to accommodate vertical ducting from ground floors.
- Site installation can be poorly carried out, with sharp bends and excessive lengths of ducting causing flow restrictions.

HYBRID SYSTEMS

A combination of both PSV and extract fans is permissible and is a solution growing in popularity with some housebuilders. PSV is installed in the bathrooms and an extract fan in the kitchens. The benefit of PSV is that there is no noise disturbance at night.

DESCRIPTION

A PSV system comprises vents located in kitchens and bathrooms, connected via near-vertical ducts to ridge or tile terminals. Warm, moist air is drawn up the ducts by a combination of the stack effect and wind effect. Replacement dry air is drawn into the property via trickle ventilators (or similar) located in the habitable rooms, and air leakage. Depending on the conditions, a minimum ventilation rate is achieved.

Guidance on design and site installation is given in BRE's Information Paper (IP) 13/94, 'Passive stack ventilation in dwellings'^[5], and third-party certification.

Ducting is available in circular and rectangular sections for flexibility of layout.

CONTROL

Standard PSV systems have a simple inlet grille to the duct. Humidity-sensitive inlets are available which provide increased flows when humidity is high (eg during periods of moisture production). These give enhanced energy performance as air extraction is minimised when moisture production is low.

Acoustic treatment of the systems to reduce external noise ingress is possible where external noise levels are likely to be a problem.

Fire dampers are required where ducts pass a fire-separating floor.

INSTALLATION

During installation, care should be taken to ensure that ducts are installed as near vertically as possible, with no more than two bends. Bends should be no greater than 30° to the vertical to minimise the resistance to air flow. Ducts should be insulated where they pass through cold spaces to prevent formation of condensation. Ducting should be fixed securely to the inlet and outlet terminals, and regularly supported throughout their length to avoid them becoming disconnected. A single duct should run to each terminal.

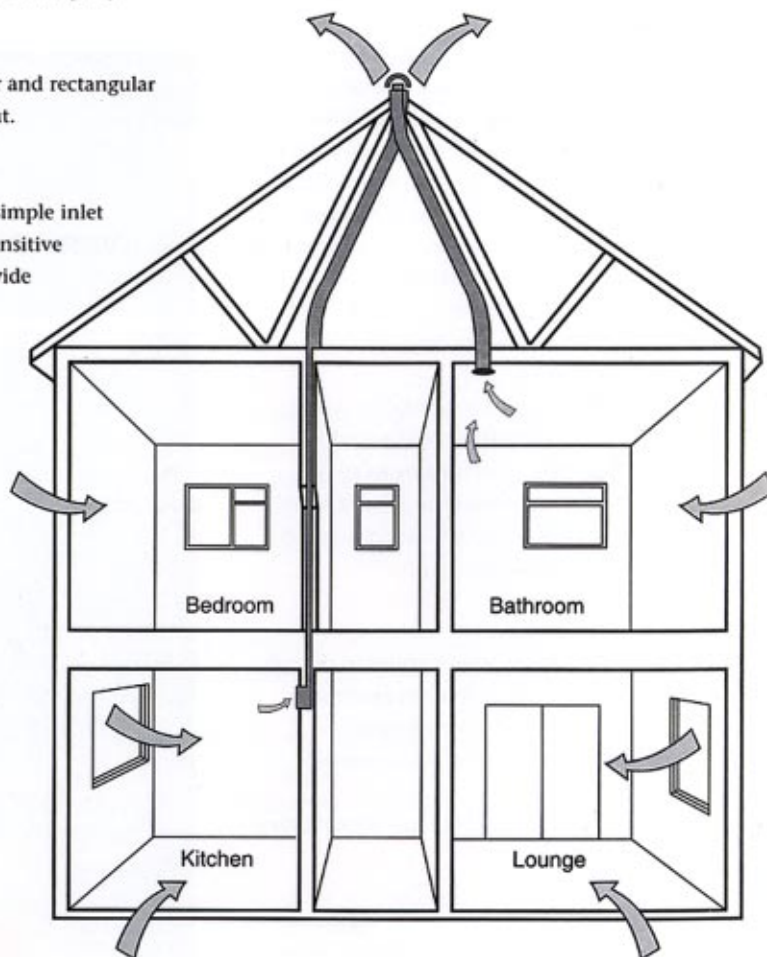


Figure 7 Passive stack ventilation

7 LOCAL EXTRACT FANS

DESCRIPTION

Local extract fans are installed in kitchens and bathrooms and provide rapid extraction of moisture and other pollutants. These do not normally operate continuously, but are either under occupant control or humidity-sensor control. Fans are widely used and can be either mounted in a window, ceiling or external wall. When ceiling-mounted, the extract should be ducted to outside. Replacement dry air is provided via trickle ventilators (or similar) and air leakage.

Care should be exercised in choosing a location for extract fans to ensure draughts are not produced, and that combustion gases are not drawn into a room from open-flue appliances. Building Regulations Approved Document F provides guidance on reducing extract rates if this is likely.

CONTROL

The simplest fans are manually controlled via a switch, or wired into the light switch. Fans can be used with a humidistat sensor and a manual override facility, although, depending on the type, some sensors may operate the fan when not required, for example in warm, humid summertime conditions. The sensors should be sited with consideration to where the main source of moisture generation is within the room. Manufacturers' installation and commissioning instructions should be followed carefully.

MAINTENANCE

Occasional cleaning to remove deposits of grease and dust is required to maintain fan performance. Fans will require replacement during the life of the building.

APPLICATIONS

- New build.
- Minor refurbishment.
- Major refurbishment.

ADVANTAGES

- Simple, widely applicable systems.
- Provide rapid extraction of pollutants.
- Can be manually or automatically controlled.
- Operation is easily understood.

DISADVANTAGES

- Perceived by occupants to have high running costs.
- Noise.
- Prone to occupant tampering.
- Requires maintenance.

8 HEAT RECOVERY ROOM VENTILATORS

DESCRIPTION

Heat recovery room ventilators are a development of the extract fan. They incorporate a heat exchanger which recovers approximately 60% of the heat from the outgoing air. This is passed across to the incoming air to preheat it. The extract fan is often dual speed, providing low-speed continuous 'trickle' ventilation, and high-speed 'boost' extract. High-speed extract can be controlled manually or via a humidistat.

Performance monitoring of these fans, carried out under the Best Practice programme, has demonstrated them to be successful at lowering the overall relative humidities. Their performance was compared with conventional extract fans with humidity control and properties relying on natural ventilation.

The design considerations for locating these fans are similar to those for extract fans.

CONTROL

The fan runs continuously at low speed; a boost to the extract rate can be via manual switching or a suitably positioned humidistat.

MAINTENANCE

Occasional maintenance is required to remove dust and grease from the fan, heat exchanger and filters. As with conventional extract fans, these need to be replaced periodically.

APPLICATIONS

- New build.
- Minor refurbishment.
- Major refurbishment.

ADVANTAGES

- Provides continuous 'low-level' background ventilation.
- Provides rapid extract ventilation, under manual or humidistat controls.
- Recovers up to 60% of heat from extracted air.
- Almost silent in operation at trickle speed.

DISADVANTAGES

- Occupant perceptions about running costs.
- Require maintenance/replacement.
- Some recirculation possible due to close proximity of supply and extract grilles.

9 MECHANICAL SUPPLY VENTILATION

APPLICATIONS

- Minor refurbishment.
- Major refurbishment.

ADVANTAGES

- Simple, widely applicable systems.
- Operation is easily understood.
- Any heat gain to loft space is utilised.
- Air can be filtered before it is delivered to the occupied space.

DISADVANTAGES

- Perceived by occupants to have high running costs.
- Noise.
- Prone to occupant tampering.
- Requires maintenance.
- Limited research into their use.
- Effectiveness dependent on building shape and layout.

DESCRIPTION

A fan, typically mounted in the roof space, delivers air into the dwelling via the landing. This creates a slight positive pressure in the dwelling. With these systems, excess water vapour is not directly extracted from kitchens or bathrooms. Water vapour has to find its way out by means of either purpose-provided openings or air leakage routes. Fans typically run at low speeds continuously with a manual or humidity-controlled boost to a higher speed if required.

CONTROL

The systems deliver a continuous flow of air to the dwelling. Fan speed can be increased by occupant or automatic switching.

MAINTENANCE

As with other fan systems, occasional cleaning is necessary. Intake grilles (fitted to most units) will need occasional cleaning/replacement.

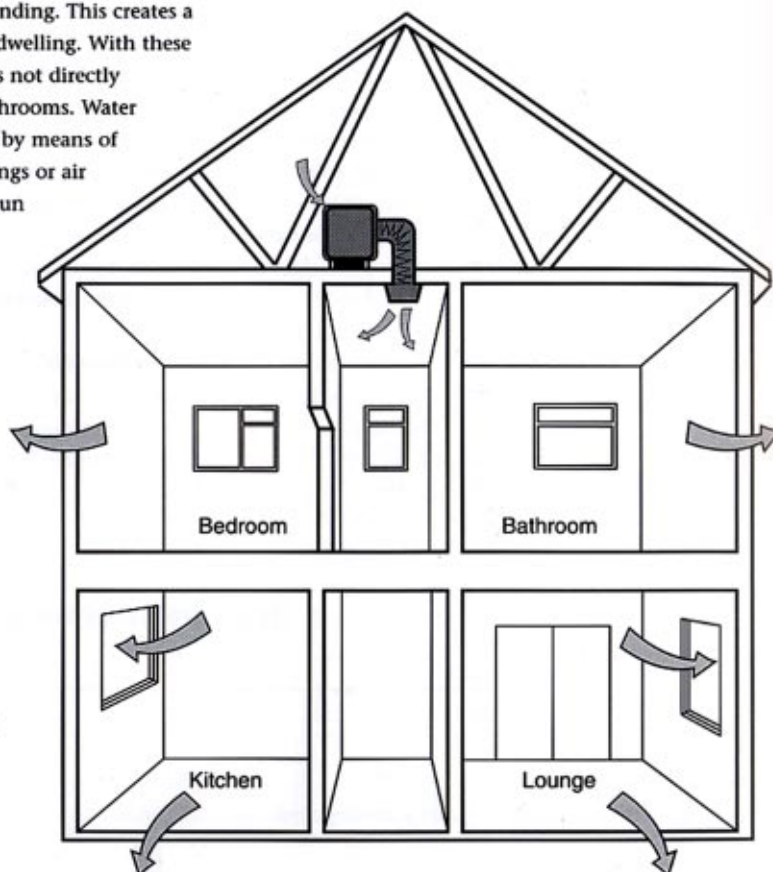


Figure 8 Mechanical supply ventilation

10 WHOLE-HOUSE MECHANICAL VENTILATION

DESCRIPTION

A whole-house mechanical ventilation system usually combines supply and extract ventilation in one system. Systems considered here incorporate a heat exchanger to preheat the supply air using heat recovered from the outgoing air. These systems can be effective at meeting part of the heating load in energy-efficient dwellings, and helping to adequately distribute the heat. Typically, warm, moist air is extracted from kitchens, bathrooms, utility rooms and WCs via a system of ducting and passed across a heat exchanger before being exhausted to outside. Fresh incoming air is preheated via the exchanger and ducted to the living room and other habitable rooms.

These systems can provide the ideal ventilation system, delivering the required ventilation rate almost independently of the weather conditions. However, to be most effective, the building fabric must achieve a good standard of airtightness, typically better than 4 ach at 50 Pa.

There are a number of non-energy benefits claimed for the systems. They are particularly effective at significantly reducing the risk of condensation, and as a consequence of the airtight structure and controlled ventilation rate, reducing cold air draughts. Manufacturers claim improvements in indoor air quality and help in controlling dust mite populations. A link has been suggested between allergic reactions, such as asthma, and house dust mite populations. Research is continuing in this area.

CONTROL

The air flows through the systems should be balanced when installed. A boost in extract rates can be provided from bathrooms and kitchens during times of high moisture production.

The systems can be acoustically treated to reduce the ingress of external noise if required, and should be provided with fire dampers where separating walls or floors are passed through.

MAINTENANCE

Regular six-monthly or annual maintenance should be carried out to ensure they are still in balance, filters are clean and the system is functioning correctly.

Fans and heat exchangers will also require occasional maintenance (dependent on filter effectiveness).

APPLICATIONS

- New build.
- Major refurbishment.

ADVANTAGES

- Controlled, preheated fresh air throughout the house.
- Heat exchanger reduces heating demand in very airtight dwellings.
- Reduces risk of condensation significantly.

DISADVANTAGES

- Accommodating ductwork.
- Initial costs are high, but increasing market demand will reduce these.
- Ongoing maintenance liability.
- For optimum performance, an adequate level of airtightness must be achieved, which can be difficult in existing dwellings.
- Complexity of installation and commissioning.

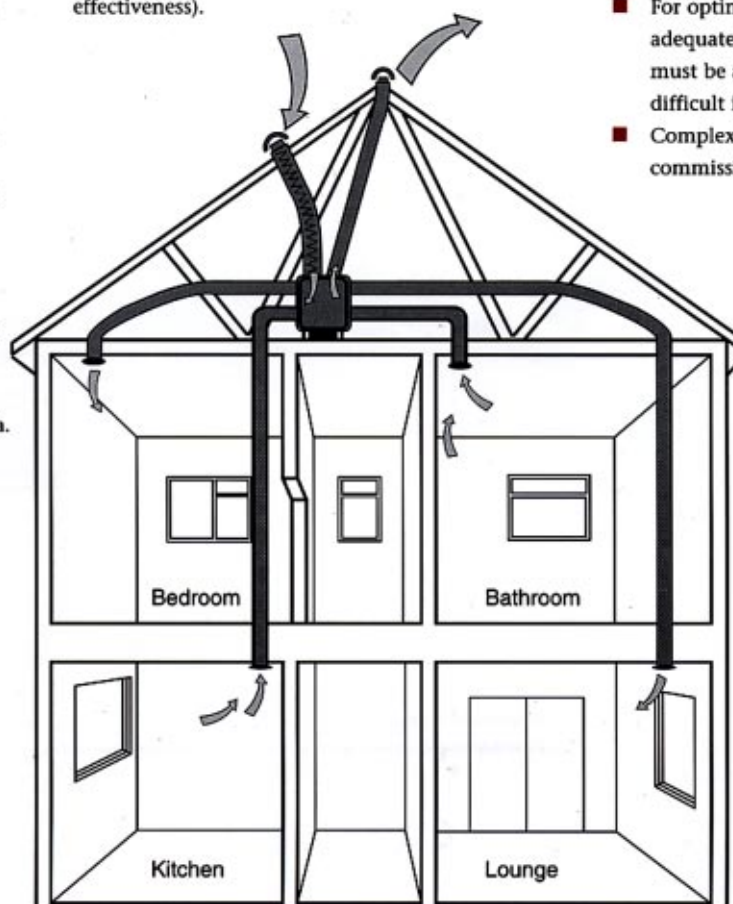


Figure 9 Whole-house mechanical ventilation

REFERENCES AND FURTHER READING

REFERENCES

- [1] *Building Research Establishment*. Digest 297 'Surface condensation and mould growth in traditionally-built dwellings'. BRE, Garston, 1985.
- [2] *British Standards Institution*. BS 5250. 'Control of condensation in buildings'. BSI, London, 1989.
- [3] Perera M D A E S and Parkins L M. 'Build Tight – Ventilate Right'. *Building Services Journal*, June 1992. CIBSE, London, 1992.
- [4] Stephen R K. 'Determining the airtightness of buildings by the fan-pressurisation method: BRE recommended procedure'. *Occasional Paper PD 57/88*. BRE, Garston, 1988.
- [5] *Building Research Establishment*. IP13/94. 'Passive stack ventilation in dwellings' BRE, Garston, 1994.

DETR ENERGY EFFICIENCY BEST PRACTICE PROGRAMME DOCUMENTS

The following Best Practice publications are available from BRECSU Enquiries Bureau. Contact details are given below.

Good Practice Guides

- 93 Energy efficiency in new housing. Detailing for designers and building professionals. Key detailing principles
- 94 Energy efficiency in new housing. Detailing for designers and building professionals. Ground floors
- 95 Energy efficiency in new housing. Detailing for designers and building professionals. External cavity walls
- 96 Energy efficiency in new housing. Detailing for designers and building professionals. Windows and external doors
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- 110 Energy efficiency in new housing. Site practice for tradesmen. Pitched roofs: insulating a room in the roof
- 224 Improving airtightness in existing homes

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